Next Generation Learning Platform - Reference Architecture based on open standard

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Abstract **–** There are hundreds of companies developing learning tools and capabilities; however, there are not many papers published on how these technologies are interconnected to provide a complete learning architecture. Because of the lack of comprehensive open learning architecture, education companies are forced to piece together many technologies and hardwire them through a non-standard integration. In recognizing the lack of progress on learning management tools, Educause proposed a conceptual framework called the next-generation digital learning environment (NGDLE). This paper explores NDGLE and suggests a reference architecture based on open standards.

1. INTRODUCTION

Education delivery has increasingly become digital. If we turn the clock back just for a few decades, learning happens only when the learner and the professor are at the same time and place. The limitation of establishing close proximity of a learner with a professor has been mitigated through distance learning primarily using postal mail. With the advent of Internet, distance learning has evolved significantly in the last decade and online learning replaced the content delivered through postal mail. The advance in online learning is not just a way to bridge the physical barrier but a new way to teach with a much richer data set that is not available in the physical delivery model. Because of the rich data set that online platform provides as well as the personalization capabilities, it has become a new type of learning called digital learning.

Online education has recently taken much wider role mainly through a new form of delivery called massive open online education (MOOC). The MOOC term started in 2008 as a peer learning model, but in 2012, it becomes more popular with the course given at Sandford University and formation startup companies focusing on the delivery model (Meltem,2015).

The most popular MOOC platforms like Coursera, EDX, and Udacity enjoy millions of users, thousands of degrees seeking students and much wider popularity

however there is no clear answer if this is the new learning delivery for the digital university or universities continue to run their own learning platforms. There is however an equal uptake by universities on investing in their leaning platform through a combination software as services and on-premise delivered solutions.

The paper discusses potential architecture for universities building the next generation learning platform, which captures the full learning experience of the learner, including courses delivered outside the learning management system (LMS). The architecture explores the including of emerging technologies like Blockchain for capturing verified learning record on the subset of the architecture.

Even though the overall concept that I will discuss in this paper is applicable to education in general, it will be primarily focusing on learning in the context of higher education.

2. RELATED WORK

One of the works on this area is a paper by Boticario which describes adaptive learning management systems as an extension of the current learning management capabilities (Boticario,207). It explores standards-based architecture based on IMS Global specification which includes IMS learning design (LD), test interoperability (QTI) and adaptation engine.

Another attempt is to bring the monotonous learning platforms in to standards based modular architectures is a paper by Seridi. The proposal calls for a service-oriented architecture model to modernize learning platform architecture from the current state of monothetic approaches (Seridi,2019). The service-oriented architecture consists of a web services bus connecting four types of web services with the identity and access management foundation. The web services that are course, cognitive testing, collaboration, and tutoring web services.

There are many competing visions by different institutions on the future of the digital learning platform. Educause has proposed a concept called the next-generation digital learning environment (NGDLE) as the successor of the currently dominant learning management systems (Brown,2015). Advanced Distributed learning puts the various standards under one umbrella called Total learning Architecture (TLA) based on a paper Total Learning Architecture: Moving into the Future (Smith, 2018). IMS Global also has a similar approach to the TLA. The

three attempts above are based on the concept where the learning community has a chance to assemble the components.

3. ARCHICECTURE FRAMEWORKS

The proposed work on this paper is to study the various learning platform architectures available publicly and recommend the next generation learning platform architecture that takes advantage of open educational standards and advances in emerging technologies. The paper will be a useful guide for an institution that wants to build the next generation learning platform and how it takes advantage of the existing and planned interoperability standards.

The paper will explore the most recent standards by Advanced Distributed Learning (ADL), IMS Global consortium, and IEE Learning Technology Standards Committee (LTSC). In addition, it will explore advances in blockchain technology as related to the education platform.

The first problem to solve in this exploration is which architecture framework(s) provide the most interoperable architecture and free up the data and learning trapped in an isolated tool. An open and interoperable framework provides an avenue for rapid growth in the adoption of learning technology by taking the complexity involved with integration.

The second problem to explore is capturing learning outside the classroom and the learning platform, which traditionally not accounted for in the development of the learning architecture framework. New standards like Advanced Distributed Learning (ADL) Experience API (xAPI) and IMS Global Caliper will be explored in this space.

The third problem to solve is exploring the applicability of emerging technologies like Blockchain in capturing the learning as immutable record and independently verifiable achievement.

The method of exploration is studying the various open standards available, interview IMS Global leaders and participating in the open standard regular meetings. The analysis of the material is mainly qualitative using my own personal experience in the digital learning platform architecture.

4. NEXT GENERATION DIGITAL LEARNING ENVIRONMENT(NGDLE)

In 2015, Educause, in collaboration with the Bill and Melinda Foundation, released a study on the future of digital learning system in higher education (Brown,2015). The goal of the study was to analyze the gap between the current learning tools and the digital learning needs of high education. The study recommends a set of frameworks that the next generation learning should have, and since no product can perform all functions, it needs to be built component by component. Each component of the module should interoperate with the other a "LEGO" and collectively called the next generation learning environment (NGDLE).

The NDGLE framework consists of five basic components which are described below.

4.1 INTEROPERABILITY AND INTEGRATION

The interoperability and integration framework describe how the various learning tools come together as one to support seamless integration for the learner. The learning environment primarily built for the learner and thus should provide a unified experience in the learning delivery.

The various tools that support NDGLE are integration through open specification standards like IMS Global with minimal friction to the institution that deploy the capability. The component of this model should also allow data sharing as the different tools are connected together.

4.2 ANALYTICS, ADVISING, AND LEARNING ASSESSMENT

Assessment in learning is a critical component, and it has been one of the focuses for educators throughout the evolution of digital learning. The assessment includes both summative and formative based on the individual need of the learner.

The advising component contains planning and advising focusing on student success. It will encompass functions that guide the learner to successful completion.

The learning component captures the learner activity both inside and outside the learning management tools. The course learning analytics is key in driving the personalization of the material to the learner.

4.3 PERSONALIZATION

One key advantage of digital learning is the ability to personalize learning based on individual needs. A system that supports personalization presents different materials for learners based on their unique circumstances.

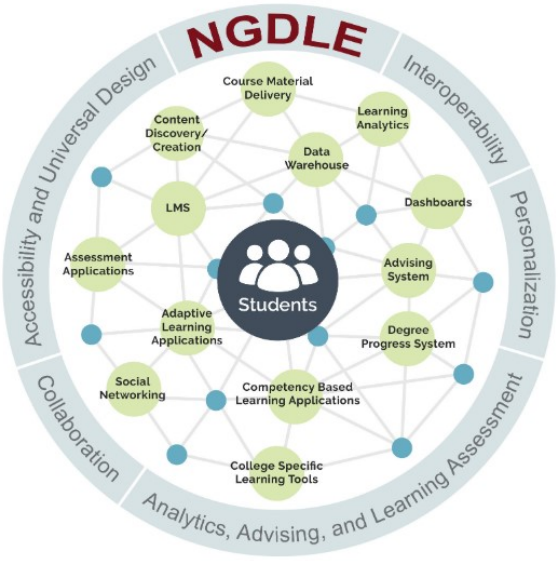
4.4 COLLABORATION

The collaboration component calls an effective way to break the barriers related to digital communication.

4.5 ACCESSIBILITY AND UNIVERSAL DESIGN

A key component of education is universal access to every irrespective of one's disability. The next-generation learning tool should include accessibility options and accommodate learners of a different type. The second component of this framework is learner experience on the end-user platform used to access the learning technology.

The picture on the right describes a high-level architecture of NGDLE with the five frameworks encapsulating the various learning capabilities.



NDGLE framework - Retrieved from: http://ulta.umn.edu/next-generation-digital-learning-environments-ngdle

5. IMS GLOBAL STANDARDS

IMS Global has been the leading standard body in the learning technologies space and published many standards that enables the interoperability of learning systems.

5.1 LTI ADVANTAGE

The LTI Advantage is the latest specification in the learning tools interoperability (LTI) toolset. LTI advantage is not one specification but rather a collection of many related specifications bundled as one. The LTI standard specification securely connects the learning management system (LMS) with learning object repositories in a manner that doesn't need custom development.

The LTI specification has been updated over many years with version 1.1 as the most widely adopted standard. The latest version LTI advantage comes with three extensions namely names& roles provisioning, deep linking and assignment and grade services. In addition to the above three extensions, it is also extensible for future enhancements.

5.2 IMS COMMON CARTRIDGE

IMS common cartridge standard is a set of open standards used by content developers and learning platforms to enable interoperability between content and systems. Common cartridge is a royalty free standard developed by global industry consortium.

5.3 CALIPER ANALYTICS

The IMS Global Caliper standard the capture of learning activities through a set of pre-defined profiles. The profile encapsulates events that itself encapsulate entity, action, and properties. The caliper profiles use a JavaScript Object Notation for Linked Data (JSON-LD) format to represent data and IMS is currently working to support Message Queuing Telemetry Transport (MQTT) protocol.

6. ADVANCED DISTRIBUTED LEARNING (ADL)

6.1 SCORM (SHARABLE CONTENT OBJECT REFERENCE MODEL)

The first standard that is universally accepted by the e-learning community is Sharable Content Object Reference Model which is known by its abbreviation SCORM. As its name implies, SCORM is focused on sharable content object (SCO) and reference model (RM). SCORM is a collection of technical specifications designed for sharing content and delivery through a learning management system (LMS).

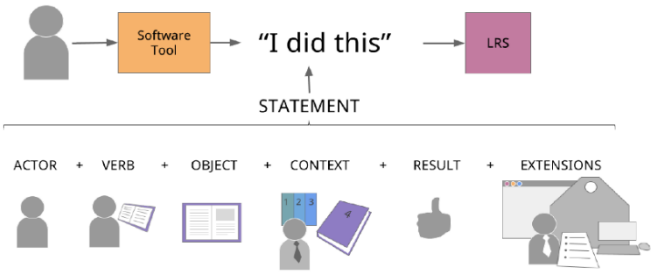
The SCORM specifications have three components, namely the content aggregation module (CAM), the runtime environment (RTE), and the sequencing and navigation (SN). The CAM module provides a mechanism to organize the learning module into learning content. The RTE mechanism makes learning content repeatable and interoperable. The SN module arranges the sequence of learning modules and learning content navigation.

6.1 XAPI (EXPERIENCE API)

SCORM is the most widely used and adopted standard; however, it only captures a limited set of data about the learner. As the complexity of the learning platform increases and more types of learning become available, there is a need for a better standard. The new standard that captures what traditionally covered by SCORM and many more is called Experience API. The Experience API is sometimes called Tin Can API or simply XAPI. The XAPI is an activity steam-based specification where any information can be propagated to what is known as Learning record store (LRS). The LRS unlike LMS doesn't need to host or support learner enrollment and this can be a standalone application by itself.

The XAPI specification captures information in English like format with three mandatory statements and two optional parameters. A typical activity statement has an actor, a verb, and an object followed by context, result, and extensions. The extensions provide flexibility for cases where the standard specification does not need the requirement.

The picture on the right describes an xAPI statement.



Source: https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=8423185

6.2 XAPI VS CALIPER

XAPI and Caliper are serving the learning analytics framework with each approaching the problem slightly in a different way. Caliper is a centrally managed

standard where only IMS Global can create and publish new profiles. XAPI took a slightly different approaching by letting the community maintain and adopt the creation of profiles.

7 IEEE LEARNING TECHNOLOGY STANDARDS COMMITTEE (LTSC)

The IEE LTSC team is actively working on a set of standards by aggregating what has been in the market already. The sub workgroup for total learning architecture (TLA) has compiled XAPI, Caliper and other related data with a draft that is to be released in the first quarter of 2020.

8 MOOC PLATFORMS

In recent years, Massive Open Online Courses (MOOCs) platforms are shifting to credit bearing education delivery and become providers of digital courses. These platforms are built by a single entity without the participation of learning technology communities. The most dominant MOOC platforms in the USA are EDX, Coursera and Udacity. Udacity has shifted the focus from delivering higher education to employment driven short courses whereas EDX focuses on higher education. Coursera focuses on almost all of the core area balancing out short term and academic programs.

9.0 EMERGING TECHNOLOGIES IN EDUCATION

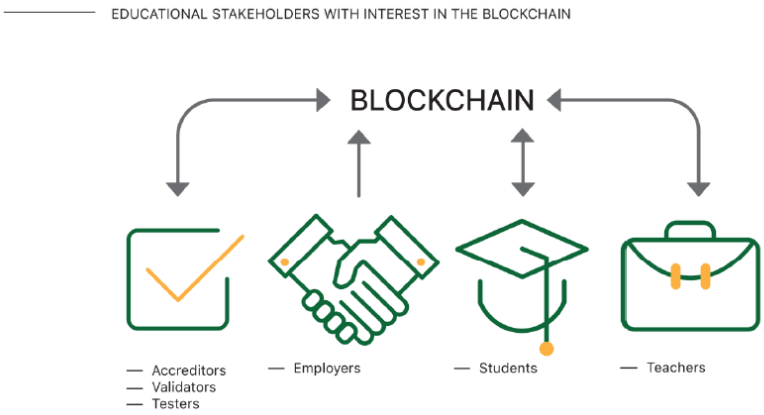
9.1 BLOCKCHAIN

Blockchain is a distributed ledger that stores records immutably. The technology is hyped as a transformational technology in digital economies with an application in many sectors. The most prevalent and widely used application of Blockchain is Bitcoin. The Bitcoin application of Blockchain is also known as public Blockchain. In the case of Bitcoin, recorded transactions need to pass through a series of cryptographic checks before confirmed for writing. The type of work that is needed to prove the validly of the transaction is called proof of work (Shi,2006). The idea of proof of work is to prevent double-spending problem so that the digital currency is not spent more than once.

The popularity of the Bitcoin and the fact that the use case applies to many other areas has opened a new possibility for the technology. There are currently a series

of developments in the Blockchain area, which include other competing implementations like Ethereum. The Ethereum protocol developed for transactions and supports what is known as smart contracts (Albert,2018). The Blockchain deployment of Bitcoin and Ethereum is known as public Blockchain. These types of deployment are open for anyone to join and thus are not suitable where identity verification is important.

Blockchain has many applications in Education and the most widely referred use cases is digital credentials. Digital credential is a form of credential that is cryptographically signed by the issuer and can be verified independently of the issuer. It is not a simple replacement of electronic and paper credential rather a new form of store for life time achievement credit.



Source: http://publications.jrc.ec.europa.eu

In the picture above, there will be a consortium of Education players who share a distributed ledger in a model known as permissioned Blockchain. The universities attest that the student graduated from college and include relevant data as a major, grade, and project profiles. The employers then verify that the degree is granted to the student without leveraging an intermediary.

There are two types of standards are now in development in relation to digital credentials. The first one is called Open Badges which is maintained by IMS Global and doesn't mandate Blockchain as a protocol. Open Badges are primarily used to motivate learner and usually considered lower level credentials compared to high stake diploma (Jovanovic,2015). Digital credentials on the other hand are for high stake credentials like completion of a degree diploma and thus need a high level of verification. There has been an open standard on diploma however

MIT and Learning Machine have released an open source formatting called Blockcerts (Blockcerts).

9.2 CONVERSATIONAL INTERFACES

As learning become more digital, learners need to communicate over a digital medium on questions about homework, materials covered in the class and other related questions. The communication could be in two forms where the first one if a direct access to teaching assistants or professors and other second one is an automated bot supporting the teaching staffs.

In the NGDLE framework, collaboration is one key component for the enablement of the next generation learning framework. One of the emerging technologies in this space is the development of artificial intelligence enabled bots.

10 PRPOPOSED REFERENCE ARCHITECTURE

I would like to provide a hypothetical scenario that outlines a real case scenario to provide a context around the proposed architecture. Imagine you have a chemistry professor who wants to bring his/her course online and also wanted to use all the latest technology available for the class. The professor sat down with the learning technology team and discussed what is currently available from the school to successfully deliver the course. The learning team presented the Blackboard learning management system and the Kaltura video authoring platform. The professor then asked to use a digital textbook, an online chemistry lab provided by a third party, a fully interactive quizzes embedded in the video lectures, and an online tutoring platform for teaching assistants to assist students who need extra practice. In addition, the leadership of the institute wanted to know how closely this program runs so that it can be used as a testbed for more science courses that will soon be offered fully online. The report should include detailed engagement experience, student's usage of the various learning tools, and a prediction model of students at least six to eight weeks ahead of the semester. There are also some students who applied for accommodations, and the system should provide equal opportunity for those with disabilities.

The first step in putting together a reference architecture is identifying the various logical components that constitute the digital learning architecture. The section

below discussed the different components that make the next generation digital learning architecture.

10.1 IDENTITY, ACCESS, PROFILE AND PERSONALIZATION LAYER(IDM)

The identity and access management layer is a core component of the learning management system and serves to separate the learner, instructor, and administrator experiences. In the case of the learner, it is the first module that a learner interacts within accessing educational content. The layer can be further extended by including a user profile and personalization data so that the learner is presented with relevant information upon login to the system.

10.2 LEARNING INTEGRATION HUB

The learning integration hub is a middle layer that service as a service hub for all learning related components. The architecture calls for a hub/spoke approaches where all internal communication between the various learning modules happens through this layer instead of a point to point integration.

10.3 CONVERSATIONAL INTERFACES(CI)

The conversational interfaces is an externally facing communication capability that enables a seamless communication between the learner and professor, teaching assistant or automated bots. In a case where the number of students far out strip the teaching resources, the automated bots answers the most commonly asked questions leaving the most complicated one to humans.

10.4 LEARNING RECORD STORE (LRS)

The learning record is a central repository for learning-related activities where every interaction between a learner and a resource is recorded. The idea of an LRS is that it creates an activity stream of events where the school run analytics. The output of an LRS could be an intervention, a customized learning pathway, or rearranging of learning delivery.

10.5 LEARNING MANAGEMENT SYSTEMS (LMS)

The learning management is the core of many of the learning delivery platform with the most widely adoption of all other modules. The LMS has been the center

of delivery for both traditional and digital learning acting as a grade book and a central repository of learning materials.

10.6 COMPREHENSIVE LEARNER RECORD (CLR)

The CLR learner record consists of digital credentials that are earned by the student as well as project portfolio and other mastery skills acquired during the academic study. The goal of the comprehensive learner record is to provide a single stop interface that accumulates all demonstrable output so that potential employers subscribe and validate instantly.

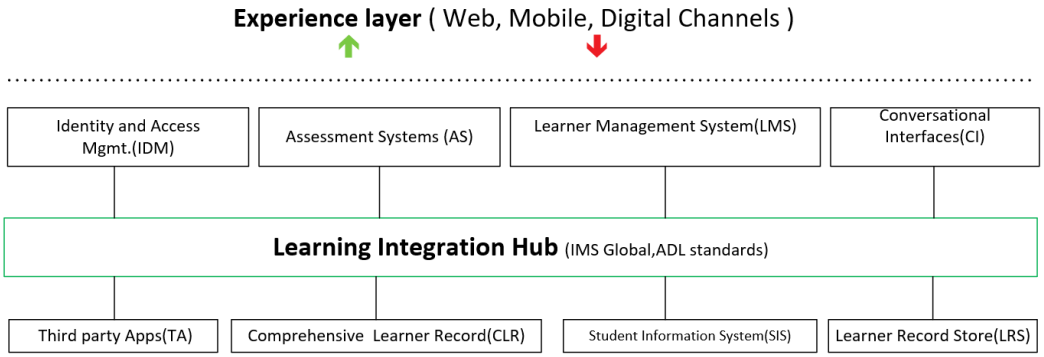
10.7 ASSESSMENT SYSTEM (AS)

The assessment systems are external or pluggable systems that curate and administer tests on behalf of the learning management tools. The assessment system should support an automated propagation of results to learner record and management tools with detail transcript.

10.8 THIRD PARTY APPS (TA)

Learning delivery is a complex process that needs the interaction of many tools and applications. The proposed platform should allow plugs in and third-party application that meet the unique delivery requirement of a course.

Putting the above components, one can come with a service-based architecture below based on a collection of capabilities working as one module. The Appendix below describes the standards applicable to each of the modular components.



Appendix:

The following abbreviations are used in the paper to describe the various modules and applicable standards.

IDM: The identity module covers SAML2.0 and OAUTH 2.0 and defines the authorization and authentication component of the interconnected system.

AS: The assessment cab be embedded or standalone and leverages QTI standard from IMS Global.

LMS: The core component of any learning systems and should support LTI advantage standard.

CI: The conversational standard is an entry and exit point for automated and person assisted conversations. There has not been standard developed for this but will use the industry REST protocol.

TA: There are many third part apps that augment and generally they should support LTI standard.

CLR: The CLR is a yet to be finalized standard from IMS Global and set a foundation for Blockchain based digital credentials.

SIS: The student information system is a system of record for a student and will support one roster (OR) standard

LRS: The LRS standard is an analytical layer and is supported by XAPI and Caliper standards.

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